Development of a Small, Multi-Purpose, Autonomous Surface Vessel

Alexander Leonessa
University of Central Florida
Department of Mechanical, Materials and Aerospace Engineering
4000 Central Florida Blvd
Bldg 40, Room 307
Orlando, FL 32816-2450
Phone: (407) 823-5623 Fax: (407) 823-0208 Email: aleo@mail.ucf.edu

Pierre-Philippe Beaujean
Florida Atlantic University
Department of Ocean Engineering, SeaTech Campus
101 N. Beach Rd,
Dania Beach, FL 33004
Phone: (954) 924-7051 Fax: (954) 924-7233 Email: pbeaujea@seatech.fau.edu

Frederick Driscoll
Florida Atlantic University
Department of Ocean Engineering, SeaTech Campus
101 N. Beach Rd,
Dania Beach, FL 33004
Phone: (954) 924-7221 Fax: (954) 924-7233 Email: rdriscol@seatech.fau.edu

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LONG-TERM GOALS

This work under this grant is focused on the research and development of low-cost, high-performance, mobile surface platform to provide both underwater navigation aid as well as environmental and oceanographic measurements. Specific proposed capabilities give rise to:

- mobile/real time position and communication relay;
- continuous geographic AUV position updates;
- rapid and accurate quantization of spatial-temporal environmental parameters of the operating battle-space; and
- increased clandestineness and decreased dependence on fixed acoustic positioning systems.

The long term goals of this research activity are to significantly increase the performance and affordability of small AUV systems by eliminating their need for expensive navigation equipment by providing exact position updates through an acoustic uplink system with a geographically positioned ASV. The mobile surface acoustic link shall also allow the AUV to communicate data while in transit and surveying, thus eliminating the hazardous need for AUVs to stop their mission and surface to transmit data. Finally, the ASV will also provide an additional asset for environmental

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characterization. Hence, the addition of an ASV will enhance reconnaissance capabilities of AUVs while minimizing potential vulnerabilities in the littoral and deep waters.

OBJECTIVES

The principal investigators have been previously funded for research and development in navigation, motion compensation, gateway buoy, underwater acoustic communication, and underwater technology. By merging this expertise and developing a common framework able to address the challenge of autonomous surface vessel applications an excellent synergism can be achieved. It is of primary focus that the outcome of the proposed work leads to a cost-effective, flexible and mobile platform suitable for AUV tracking, navigation, communication, and oceanographic/environmental measurement. The primary objective of the proposed work is to extend the capabilities and enhance the performance of AUV navigation, communication and environmental measurement using an autonomous surface vessel. Such an ASV is built upon:

- an existing surface vessel navigation and control package,
- a vertical communication and USBL navigation system derived from the FAU-Dual Purpose Acoustic Modem,
- a 3-D measurement algorithm which utilizes a low cost GPS/IMU/COMPASS/ADCP system.

The accurate positioning system onboard the ASV provides the AUVs with the navigation information needed for a successful mission, through an acoustic uplink system between the ASV and the AUVs below it. Onboard the ASV is a high-accuracy rapid-update GPS and a low-cost 3-axis accelerometer and rate gyro package. Using existing sensor fusion techniques developed at FAU, the fused signal from these sensors provides the ASV with sub-meter positioning. The ASV also houses the FAU Dual-Purpose Acoustic Modem that can provide the relative position of the AUV with respect to the surface vessel – in effect, a USBL. The ASV calculates the geodetic position of the AUV and broadcasts that information acoustically to the AUV – thereby recalibrating the navigation algorithms. Such a system is very useful during the transit to the work site when water depth is greater the range of the DVL and to fill in gaps in the gateway net. Additionally, the data provided by the combined ASV and GATEWAY BUOY NET reduces the navigational requirements of small AUVs – thereby reducing their cost and complexity.

Using the FAU Dual-Purpose Acoustic Modem, it is also be possible to interact with the underwater vehicle to change the mission, read gathered data and change the mission both autonomously and through an operator communicating with the ASV using an RF uplink from ashore or a distant vessel. In addition, the high quality navigation data from the ASV shall be used to indirectly measure environmental properties such as ocean currents and local wave fields. The ASV is small enough to move with the local waves. Thus, the wave field can be backed out of INS measurements and vehicle dynamic response with minimal effort. The navigation data shall also be used for motion compensation of the onboard ADCP to reduce sampling time and increase the resolution and quality of the measurements. With such instruments and motion correction algorithms, the ASV shall also be used as a mobile environmental measurement platform.

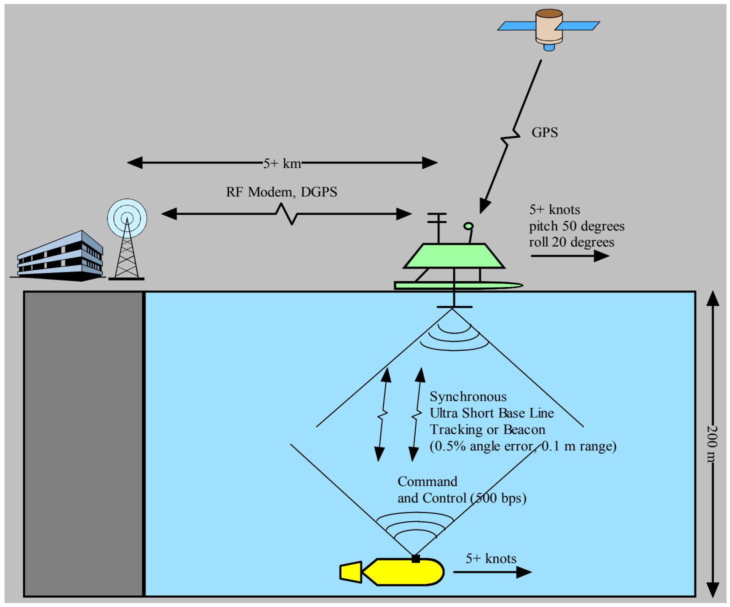

Figure 1. Pictorial view of an accurate synchronous navigation, communication and high-speed acoustic uplink system between Autonomous Surface Vehicle (ASV) and Unmanned Underwater Vehicle (UUV)

APPROACH

We divided the design of the control and navigation algorithms in three phases:

a) First, using our adaptive control algorithm, we will design and test the maneuverability of the ASV. This shall be achieved by performing, for example, bathymetry scans and navigating along iso-depth lines. This phase will not involve any communication with the underwater vehicle and can be performed in parallel to the development of the acoustic system, thus, decreasing the development time.

b) Second, a cooperative control scenario will be demonstrated. A simulated underwater vehicle (SUV, a subsurface hydrophone attached to a small RHIB) shall be navigating independently and the ASV, which will be controlled so to remain close to the SUV, will track it. During this phase we will study the ability of the surface vehicle to track the underwater vehicle and verify the performance of the control algorithm at different speeds, sea states and search patterns. During this test, simultaneous environmental data shall be collected from the ADCP. Using the fused INS/GPS data, the wave and surface current field will be backed out. The data will be verified against wave and current fields measured by existing SFOMC instruments. This phase shall demonstrate the ASVs tracking and environmental measurement capabilities.

c) Third, once both the receiving and transmitting components of the acoustic system onboard the underwater vehicle will be completed, the experiment described in phase 2 will be repeated but this time the SUV will simulate dead-reckoning algorithms using an existing AUV navigation module. Position updates, transmitted by the autonomous surface vehicle, shall be used to recalibrate the navigation routine in real time. To demonstrate the acoustic comms an operator, on a different vessel, will monitor the operating condition of the SUV in real time through an RF modem connection to the ASV and feedback mission updates.

WORK COMPLETED

The design and manufacturing of the vehicle is completed. This includes mechanical, electrical, electronic, and software design. In particular, a vehicle design consisting of two surface pontoons and one instrument payload suspended 6ft underwater was chosen (Figure 2). The surface pontoons have a large area moment of inertia and low residual resistance and they have been manufactured by casting foam over an anodized aluminum frame. The position and shape of the instrument payload lowers center of gravity and significantly decreases residual resistance. It has been built by using a fiberglass shroud around a rib cage structure. It houses the batteries in two separated pressure vessels and the sensors and computers in a third pressure vessel. Finally the ASV propulsion system consists of two off-the-shelf trolling motors.

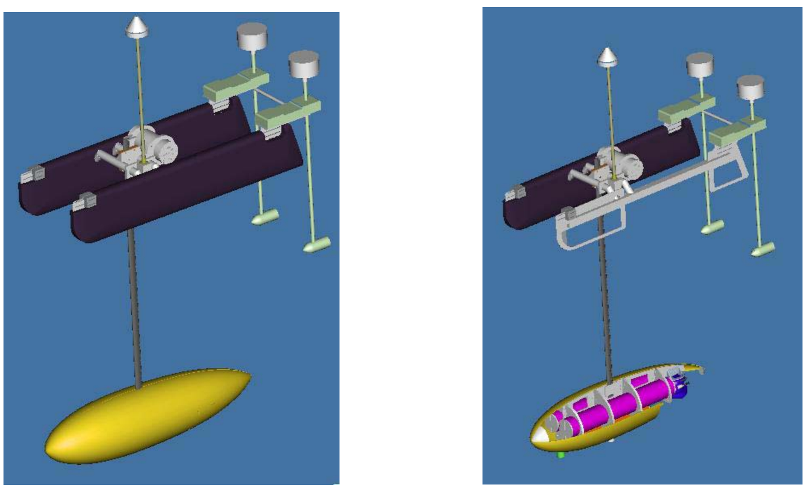

Figure 2: Autonomous Surface Vessel final design

The computers are based on PC-104 format cards and the software uses the xPC Target toolbox running in Simulink (all by Mathworks). In particular the hardware consists of two JUMPtec 166 MHz CPU boards, a Diamond serial expansion board, a Diamond AD/DA converter board and a Simpletech 1 GB Flash drive. The vehicle is equipped with Dual Purpose Acoustic Modem and an RF ethernet hub for communication purpose. Finally the sensors on board include a differential global positioning system, an inertial measurement unit, an acoustic soppler current profiler and an electronic compass providing pitch and roll angles as well. Figure 3 shows the assembly of all of the computers and sensors.

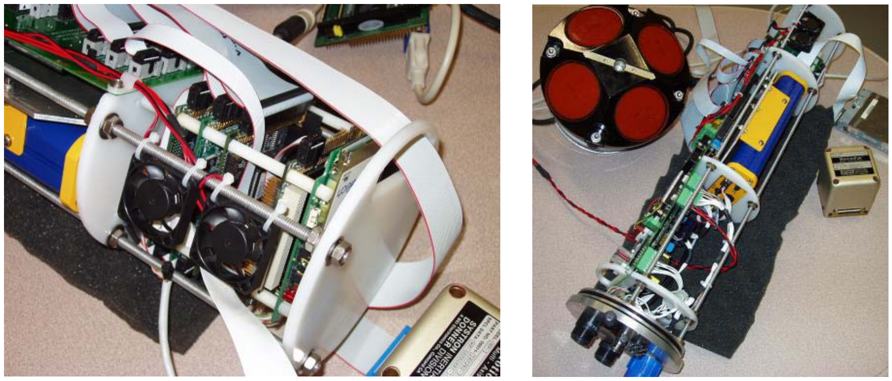

Figure 3: Computers and Sensors onboard the ASV

RESULTS

With the completion of the manufacturing of the vehicle prototype, new capabilities have been generated, including: a mobile/real time position and communication relay; continuous geographic AUV position updates; rapid and accurate quantization of spatial-temporal environmental parameters of the operating battle-space; and increased clandestineness and decreased dependence on fixed acoustic positioning systems. These capabilities are currently tested with at-sea experiments.

IMPACT/APPLICATIONS

Future applications for the Autonomous Surface Vessel include, but are not limited to: communication bridge between off-the-field operators and AUVs, positioning aid to AUVs which are not required to surface anymore, oceanographic measurements.

RELATED PROJECTS

The telemetry electronics and transducers installed in the current version of vehicle are shown in Figure 4. This package performs the following functions: low-rate acoustic communications for command and control purposes, inverted long-base line navigation (tracking and positioning modes), GPS positioning and RF communications, and an array of multiple broadband acoustic receivers mounted in a tetrahedral configuration for USBL. The advantages of a multiple element receiver array to improve communication in frequency-selective channels have been clearly demonstrated through numerous research in both acoustic and radio frequency domains. In the inverted long-base line (ILBL) mode, the buoy-mounted DPAM act as transponders, able to transmit and receive coded time information to/from any modem mounted on a vehicle. The message sent contains an identification number, a time of transmission and a broadband synchronization symbol. By comparing time of transmission and time of reception read off a low-drift clock, the FAU-DPAM is able to determine its range/bearing with respect to the beacon. This low-cost add-in makes the FAU-DPAM a cost and power efficient replacement for a regular Long Base Line navigation system.

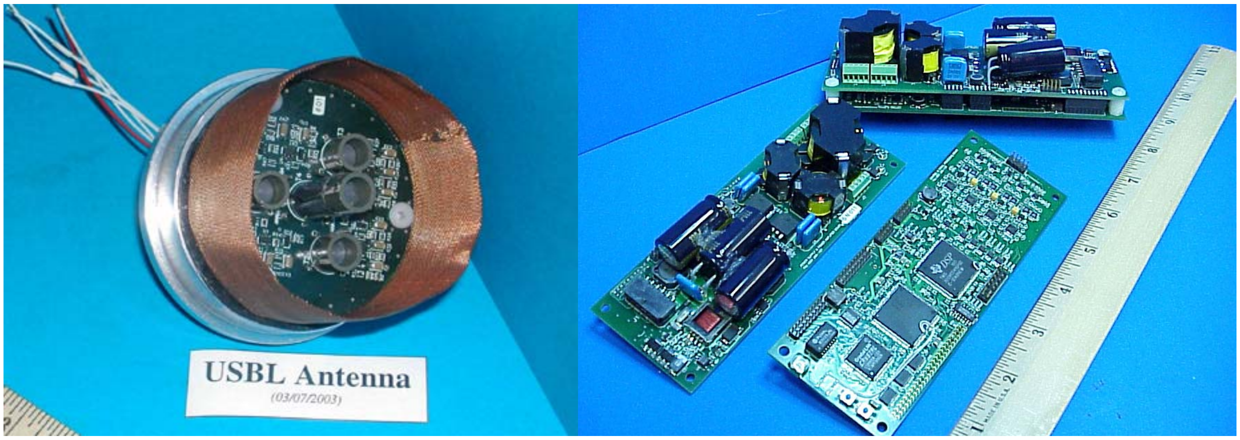

Figure 4. USBL Antenna, 4 Elements and Dual Purpose Acoustic Modem (DPAM) Embedded Electronics

PUBLICATIONS

A. Leonessa, Y. Morel, M. Vidal, J. Mandello, "Design of a Small, Multi-Purpose, Autonomous Surface Vessel," in Proceedings Florida Conference on the Recent Advances in Robotics – 2003, [published]

T. VanZwieten, "Simulation and Control of an Autonomous Surface Vehicle," in Proceedings Oceans 03 Conference, [published]

A. Leonessa, M. Vidal, J. Mandello, Y. Morel, "Design of a Small, Multi-Purpose, Autonomous Surface Vessel," in Proceedings Oceans 03 Conference, [published]

PATENTS

[pending] provisional patent.

HONORS/AWARDS/PRIZES

Ms. T. VanZwieten received an Honorable Mention at the 2003 IEEE OCEANS Conference for the poster that she presented titled "Simulation and Control of an Autonomous Surface Vehicle".